Variation in visual acuity between individuals

Visual acuity has many components, the two most obvious being (a) the ability of the eye optics to focus light onto the retina without aberration, and (b) the ability of photo receptors in the retina to resolve fine features.

This document presents some interesting graphs that address the first issue, namely the optical performance of the eye, independent of the retina. The plots are from Volume 1 of the OSA "Handbook of Optics."

While the graphs are interesting in themselves, I included them to illustrate these takeaway points:

- At pupil diameters between 2 and 3 mm, the optical system of the eye is close to diffraction limited, with resolving power well beyond the 20:20 threshold of 30 cycles per degree.
- Since most people can barely manage 30 cycles per degree, the resolution of the retina is clearly also a limiting factor.
- At larger pupil diameters the resolving power of the eye actually decreases.

There is a great deal of variation between individuals.

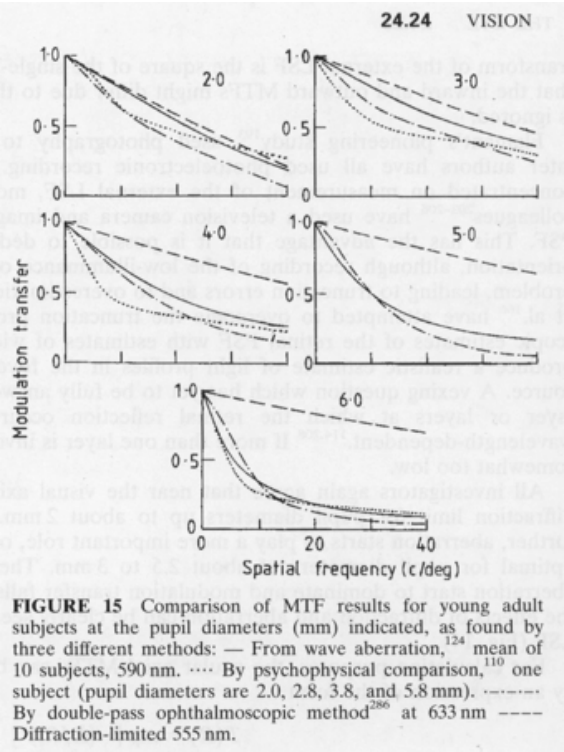


FIGURE 15 Comparison of MTF results for young adult subjects at the pupil diameters (mm) indicated, as found by three different methods: — From wave aberration,[124] mean of 10 subjects, 590 nm. ···· By psychophysical comparison,[110] one subject (pupil diameters are 2.0, 2.8, 3.8, and 5.8 mm). -·-·-· By double-pass ophthalmoscopic method[286] at 633 nm ---- Diffraction-limited 555 nm.

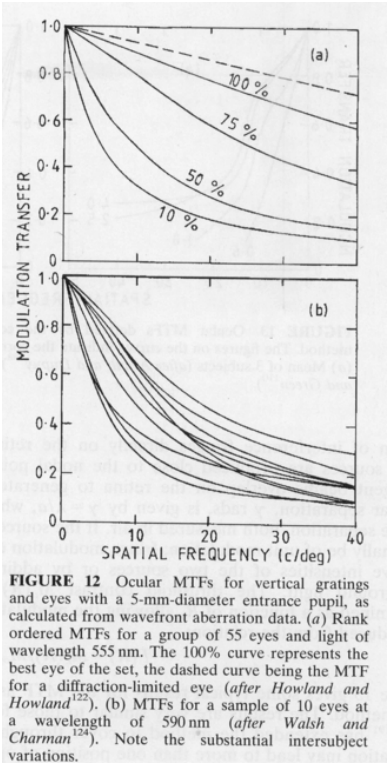


FIGURE 12 Ocular MTFs for vertical gratings and eyes with a 5-mm-diameter entrance pupil, as calculated from wavefront aberration data. (*a*) Rank ordered MTFs for a group of 55 eyes and light of wavelength 555 nm. The 100% curve represents the best eye of the set, the dashed curve being the MTF for a diffraction-limited eye (*after Howland and Howland*[122]). (b) MTFs for a sample of 10 eyes at a wavelength of 590 nm (*after Walsh and Charman*[124]). Note the substantial intersubject variations.

Figures from: OSA Handbook of Optics, Vol.1

Variation in pupil diameter

The information in this section comes from the University of Pennsylvania, to illustrate these key points:

- Pupil diameter varies with lighting level
- In a well-lit office environment of ~ 80 cd/M^2 the nominal pupil diameter is ~ 2.5 mm
- Different studies have yielded different relationships between luminance and pupil diameter.

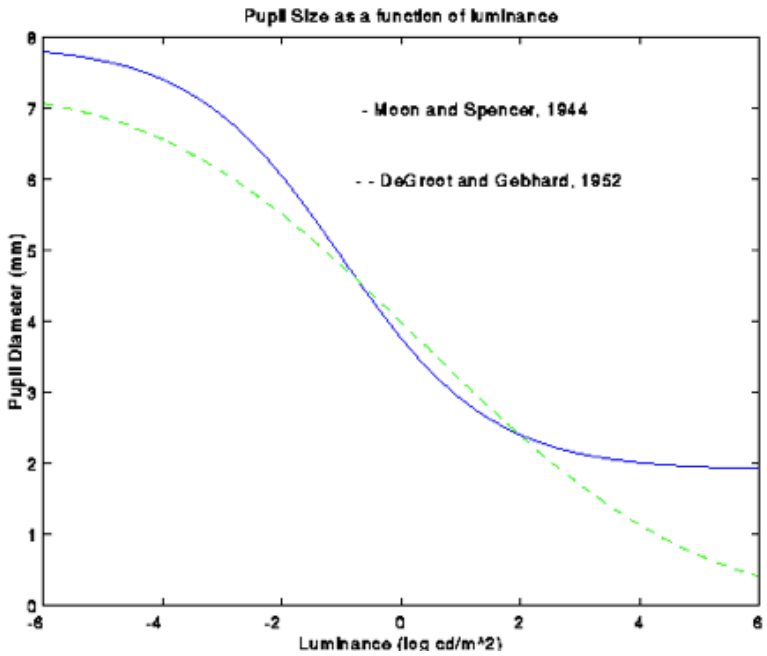
This is a reminder that the 2.5 mm value is simply a rule of thumb.

- The pupil is the "hole" in the iris that allows light into the eye.
- It changes size in response to ambient light level and other things.
- Pupil reflex appears to be triggered by a mixed cone and rod stimulation.

  (Alpern and Campbell '62)
- The pupil horizontal diameter ranges from about 2 mm to about 8 mm.
- Some empirical equations describing retina size as a function of light level are:

  Moon and Spencer (1944): diameter = 4.9 - 3tanh[.4(log L + 1.0)]

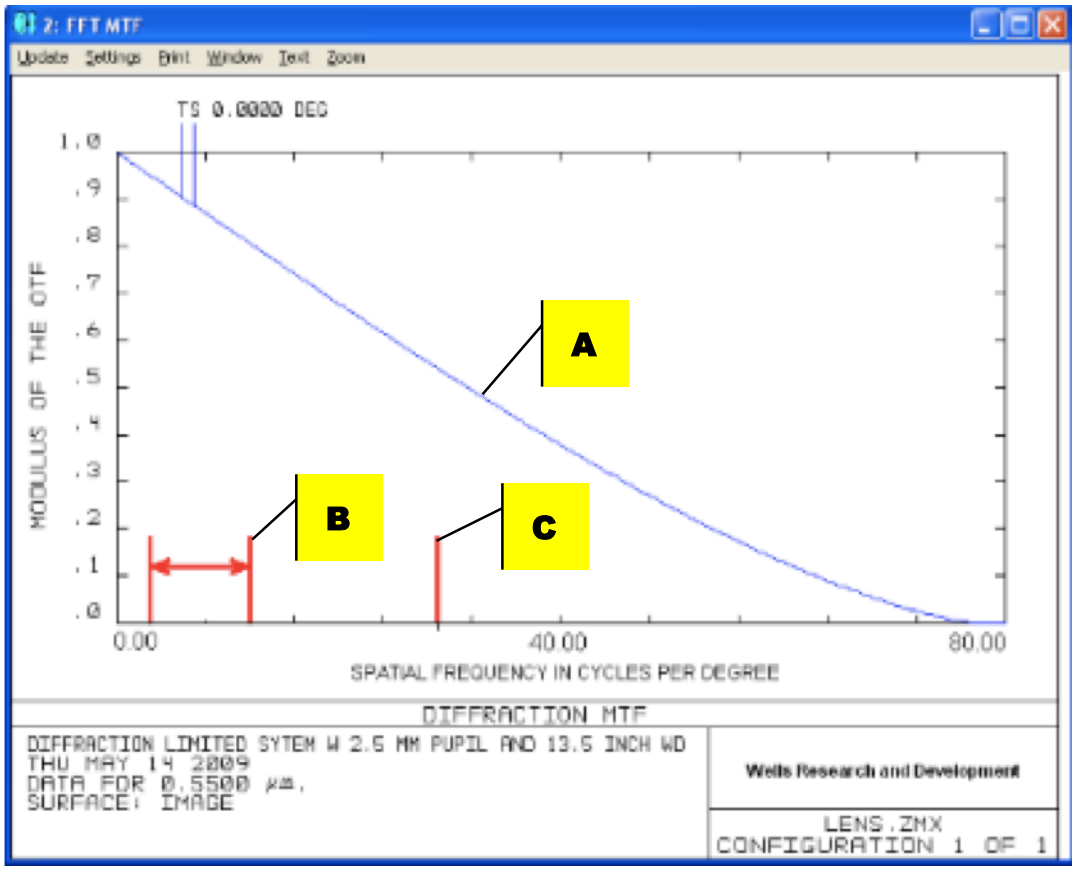
  DeGroot and Gebgard (1952): diameter = 10^(.8558 - .000401(log(L) + 8.6)^3)



Source: http://retina.anatomy.upenn.edu/~lance/eye/pupil.html

MTF and human visual acuity

The plot below was constructed in the lens analysis program "Zemax", and shows the MTF plot for a theoretically perfect optical system with an entrance aperture of 2.5 mm.



Key to captions:

[A] MTF curve for diffraction limited system with pupil diameter of 2.5 mm

[B] According to Dr. Ed Granger's SQF metric[1], the range of frequencies from 3 to 12 line-pairs per degree is all that really matters when the eye evaluates "image quality."

While higher frequencies obviously are not completely irrelevant, Grainger's SQF metric does correlate well with perceived image quality.

[C] 30 line-pairs per degree corresponds to 20/20 vision.

[1] Information on the SQF metric may be found at: proceedings.spiedigitallibrary.org/proceeding.aspx?articleid=1236329